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Naval Supremacy

Throughout all of modern military history, upon every outbreak of a geopolitical crisis, each Commander in Chief has first asked the same questions:

- How far is the closest carrier?
- How many Marines do we have at sea?
- How long will it take to get them there?

Two decades ago, the US Navy had almost 600 ships. Today's Navy has fewer than half that number. And unless a rival power emerges with a blue-water Navy, tomorrow's fleet is likely to have fewer still. This is the force-level trend for the littoral theater.

And yet, maritime supremacy is the still the most effective means to project power. The world's oceans cover two-thirds of our planet. It's the medium over which no sovereign can veto our movements. And it's the medium in which US dominance is exercised globally, with stealth.

Maritime Network-Centric Warfare

If we're to maintain maritime supremacy with a leaner Navy, it must be done by employing diverse contingents of autonomous offboard systems together with the capital platforms of the future Navy. Our naval force will be multiplied by having these systems interconnected by a robust, seamless maritime network that operates above the water, on the water, and in the water.

Imagine a navy that can deploy clandestine systems to detect, localize, and even destroy enemy forces without risking a single Sailor; a navy with an enduring and pervasive surveillance capability that reaches right onto the shores of potential adversaries; a navy that can covertly neutralize anti-access forces prior to an amphibious assault.

This is one vision for Maritime Network Centric Warfare. Now, let me underscore the word maritime. Logistically, *maritime* warfare for the US means going into all the littoral regions around the world. Since the days of the Barbary Coast, Americans have preferred to take the fight to the enemy. For this, we will always be the ones crossing the oceans to cover the global waterfront. Our "hold-at-risk" posture requires a continuing presence in distant locales with limited assets. Meanwhile, our adversaries can concentrate their own assets quickly and cheaply to defend their shores. Operationally, *maritime* means both the waterspace and airspace in the near-shore littorals, as well as the open oceans. For networked operations, this means having to deal with two radically different propagation environments, seamlessly, so all assets can operate and interoperate most effectively.

With autonomous systems and an effective network, we can achieve a strategic advantage. The enemy will be at risk from relatively small, relatively inexpensive, unmanned platforms that bring the fight to the opponent while keeping our capital assets out of harm's way.

Littorals

Taking the engagement to the opponent means fighting in their pond, literally. The littorals are a complex operating environment. Here, the waters may be shallow and the ocean floor is likely to be highly featured. The ocean surface is constantly moving with sea state and wind conditions. Also, the region is populated with marine life and civilian

boat traffic. Our systems are vulnerable to being seen and compromised. Our adversaries will have the home field advantage in electronic and acoustic warfare so our systems will have to mitigate jamming while conducting clandestine or stealthy operations.

Meanwhile, command nodes must remain at significant standoff distances. This means that long haul, high-bandwidth communications are required for effective command and control of the battlespace. The offboard systems become high-value network nodes and must be survivable and reliable in currents, winds, and high seas to be able to provide a high quality of service to the network.

Under-surface nodes must be able to communicate with surface and air nodes to maintain continuous connectivity with the battle group. This presents a major challenge. Acoustic data rates of tens of kilobits are grossly mismatched with RF data rates in mega- to giga-bits. Things such as "gateway buoys" to interconnect these two regimes become choke points in the network, and they're vulnerable to detection and exploitation by our opponents.

To deal with the harsh littoral maritime environment, we need technology innovations coupled with real system solutions to provide:

- Robust, all-weather systems that can operate in highly dynamic marine conditions
- Real and reliable connectivity to the command nodes
- Real and reliable connectivity between the RF and undersea domains

Undersea Challenges

Let's focus for a few minutes on underwater. The maritime battlespace is the only arena in which we must master the physical limits and daunting challenges of that environment. Undersea systems cannot rely on high-bandwidth, continuous, or on-demand communications that are taken for granted in the above water world. Navigation requires inertial systems, often with infrequent GPS updates. Platform speeds and sensor and weapon ranges are all severely limited in underwater systems. To network underwater, communication is a fundamental barrier. Acoustic communication is subject to severe variable attenuation and multipath spreading. The large and variable propagation delays make it difficult to measure meaningful round-trip times, which are fundamental to many communication protocols. Path fluctuations of tens of milliseconds can generate severe intersymbol interference.

These mechanisms cripple throughput, and ranges are necessarily short. Even over a relatively short distance of about 10 nautical miles, communication is limited to a few kilobits per second, leaving us with one-tenth of a dialup modem rate for communicating with critical assets. The barrier must be overcome.

The need for stealth requires the communications be clandestine. Are there novel signal processing approaches that are environmentally agile and covert? Do we try to hide in ambient noise by adapting spread-spectrum techniques? Or do we hide in plain sight, making the communications sound like whale chatter, snapping shrimp or other natural phenomena? Perhaps other communication modalities can be exploited. Only extremely low frequency electromagnetic waves propagate in salt water. This seems to make undersea networking using electromagnetic radiation impractical, but is it? Could alternate propagation paths through the sea floor or through the air partially solve the problem? Optical attenuation lengths in littoral waters can be ten meters or less. Are there acousto-optical phenomena that can serve as the basis of a robust communications link?

It's one thing to conceive of a point-to-point underwater communication link, but to network hundreds of communication nodes to operate as an effective C3 entity, self-aware and self-managing, is formidable.

As I've mentioned, acoustic bandwidth is severely limited for the link distances we want, which may

be tens of miles or more. Scaling a network to hundreds of nodes using standard access protocols would result in throughputs of mere bits per second, too little, too slow, and too late. New access schemes that conserve bandwidth and maximize capacity must be invented for the underwater space.

For mobile nodes, routing also uses up capacity. There is a trade between the overhead in route discovery and the amount of time that the route can be used. Go underwater, and this trade can be very unfavorable, the network activity becomes dominated by the overhead process. New methods of efficient packet communications are needed to take full advantage of the network. The wireless ad-hoc networking community has been dealing with some of these issues for years. We need to consider the unique characteristics of the underwater channel and see if there are opportunities to cross-fertilize ideas. As history shows, there are distinct benefits to operating underwater:

- We need to explore ways to communicate effectively underwater, whether by acoustic or other means
- We need to develop concepts that exploit other communication modalities that offer higher bandwidths and much longer ranges
- We want new ideas for mobile ad-hoc networking that minimize latencies and maximize throughputs in highly dynamic environments

All these are key to overcoming the underwater challenges for a true networked approach to maritime warfare.

Autonomous Offboard Systems

The maritime network may include hundreds, or even thousands, of off-board sensors extending the naval footprint. Sensors only provide data, though, and today the problem of turning the data into actionable information is just handed to the operator. With autonomous systems in an autonomous network, the sensor nodes must be information nodes, not just data sources. These offboard sensors must process and communicate automatically and reliably. They must have own-environment awareness to be able to optimize performance. And they must be intelligent enough to participate in the network.

Add mobility, and our autonomous platforms can act, not just observe. Consider, for instance, that today's long-range sensors keep our platforms out of harm's way, but at the price of making contact classification a difficult problem due to the weak signatures available at long range. An autonomous vehicle can close on a contact, and perhaps even identify a threat more reliably at closer ranges where the signature may be richer and the propagation path more stable. With mobility, some preemptive action may even be taken. Remember that the mobility comes at a price. Mobile systems require more power than fixed systems, and these autonomous systems need staying power, power to persist unattended for weeks, months, or even years. Batteries today are rated in watt-hours of use. Power for persistence will be rated in watt-months or watt-years. We need power sources that are long-lasting, but aren't dangerous and don't pollute. But whether we use new and exotic materials as fuel sources or invent new chemistries to generate power or harness energy from the environment, or extract it from bio-organisms, the challenge is this: an autonomous system needs low to zero maintenance on-demand power to do its job. What is the ultimate high energy-dense power source for autonomous vehicles, when volume is a premium, reliability is a prerequisite, and survivability vital to success? We need creative ideas to solve this problem.

To sum things up, we have a shrinking Navy, a big planet, and a doctrine that commits us to prepare for many distant contingencies. The maritime network is critical to a reduced fleet as a force multiplier, and we need new thinking that transcends faster, better, and cheaper substitutes for

the foreseeable solution set. The maritime network must also be integrated with the Joint Forces. It is the critical enabler to conduct operations from a sea base. It is the virtual sea base.

Let's envision the future Naval Force. There will be fewer ships casting a wide net over the vast maritime battlespace—a net that's extendable, flexible, and impenetrable—fleets, squadrons, or units of autonomous systems distributed around the world doing their jobs. Envision that, and we will achieve startling new capabilities we never before thought possible.